Refractive Interstellar Scintillation and the Search for Very-Low-Frequency Gravitational Radiation

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Very-l ow-frequency (Fourier frequencies less than ~ 1 O microhertz) gravitational wave searches involving pulsar timing use the earth and pulsar as free test masses. Gravitational waves buffeting earth and pulsar show up as pulse time-of-arrival (TOA) flue.tuatic)lis. Observed TOA fluctuations are the sum of gravitational wave perturbations (at some lewd) and "noise". Prior to the discovery of PSR 1937+21, the leading noise was intrinsic pulsar timing variability. PSR 1937+21, however, has very low intrinsic timing instability and has been used to place stringent upper limits on a VLF stochastic background of gravitational waves. A noise source important in the ultimate sensitivity of these observations is TOA fluctuations caused by propagation of the pulsar signal through electron density fluctuations in the ISM.

In this paper I calculate the contribution of refractive interstellar scintillation (RISS) noise to gravitational wave searches. Formulas relating the ISM density power spectrum, the spot.trum of TOA and relative dimensionless velocity, and inferred gravitational wave upper limits are developed and used to calculate the RISS-noise limit for VLF gravitational wave bursts, periodic waves, and backgrounds. For a standard Kolmogorov ISM turbulence model with $C_N^2 = 10^{-3}m^{-6.67}$ the timing instability caused by RISS, expressed as a fractional frequency st ability for observations at $0_0 1 2 6_n$] wavelength over an integration time τ, is $\sim 4 X 1 0^{-14}(\tau/1 year)^{-1/6}$. This is, on time scales $\sim$years, comparable to the estimated stabilities of the best atomic clocks, and corresponds to a VLF gravitational wave background limit at or near those derived from 1937+21 observations.